CLAIMS

What is claimed is:

1. A microporous membrane comprising:

a membrane body portion having a multiplicity of micropores defined therethrough, the membrane body portion having a liquid contact surface and an opposing gas contact surface, the liquid contact surface having an ultraphobic surface thereon including a substrate with a multiplicity of substantially uniformly shaped asperities, each asperity having a common asperity rise angle relative to the substrate, the asperities positioned so that the ultraphobic surface defines a contact line density measured in meters of contact line per square meter of surface area equal to or greater than a contact line density value "Λ_L" determined according to the formula:

$$\Lambda_L = \frac{-P}{\gamma \cos\left(\theta_{a,0} + \omega - 90^\circ\right)}$$

where γ is the surface tension of a liquid in contact with the surface in Newtons per meter, $\theta_{a,0}$ is the experimentally measured true advancing contact angle of the liquid on the asperity material in degrees, ω is the asperity rise angle in degrees, and P is a predetermined liquid pressure value in kilograms per meter, so that when liquid at a liquid pressure up to and including the predetermined liquid pressure value is contacted with the ultraphobic surface, the liquid defines a liquid/gas interface plane spaced apart from the substrate.

2. The membrane of claim 1, wherein the membrane is a film.

3. The membrane of claim 1, wherein the membrane is a fiber.

4. The membrane of claim 1, wherein the asperities are projections.

5. The membrane of claim 4 wherein the asperities are polyhedrally shaped.

6. The membrane of claim 4 wherein each asperity has a generally square transverse cross-section.

7. The membrane of claim 4, wherein the asperities are cylindrical or cylindroidally shaped.

8. The membrane of claim 1, wherein the asperities are positioned in a substantially uniform array.

9. The membrane of claim 8, wherein the asperities are positioned in a rectangular array.

10. The membrane of claim 1, wherein the asperities have a substantially uniform asperity height relative to the substrate portion, and wherein the asperity height is greater than a critical asperity height value "Z_c" in meters determined according to the formula:

$$Z_c = \frac{d\left(1 - \cos\left(\theta_{a,0} + \omega - 180^\circ\right)\right)}{2\sin\left(\theta_{a,0} + \omega - 180^\circ\right)}$$

where d is the distance in meters between adjacent asperities, $\theta_{a,0}$ is the experimentally measured true advancing contact angle of the liquid on the asperity material in degrees, and ω is the asperity rise angle in degrees.

11. A process of making a microporous membrane with an ultraphobic liquid contact surface, the process comprising:

providing a microporous membrane having a membrane body portion with a multiplicity of micropores defined therein, the membrane body portion having a first surface; and

forming an ultraphobic liquid contact surface on the first surface, the ultraphobic surface including a substrate with a multiplicity of substantially uniformly shaped asperities, each asperity having a common asperity rise angle relative to the substrate, the asperities positioned so that the ultraphobic surface has a contact line density measured in meters of contact line per square meter of surface area equal to or greater than a contact line density value "Λ_L" determined according to the formula:

$$\Lambda_L = \frac{-P}{\gamma\cos\left(\theta_{a,0} + \omega - 90^\circ\right)}$$

where γ is the surface tension of a liquid in contact with the surface in Newtons per meter, $\theta_{a,0}$ is the experimentally measured true advancing contact angle of the liquid on the asperity material in degrees, ω is the asperity rise angle in degrees, and P is a predetermined liquid pressure value in kilograms per meter, , so that when liquid at a liquid pressure up to and including the

predetermined liquid pressure value is contacted with the ultraphobic surface, the liquid defines a liquid/gas interface plane spaced apart from the substrate.

12. The process of claim 11, wherein the asperities are formed by a process selected from the group consisting of nanomachining, microstamping, microcontact printing, self-assembling metal colloid monolayers, atomic force microscopy nanomachining, sol-gel molding, self-assembled monolayer directed patterning, chemical etching, sol-gel stamping, printing with colloidal inks, and disposing a layer of parallel carbon nanotubes on the substrate.

13. The process of claim 11, wherein the process further comprises the step of determining a minimum contact line density.

14. A process for producing a microporous membrane having a liquid contact surface with ultraphobic properties at liquid pressures up to a predetermined pressure value, the process comprising:

selecting an asperity rise angle;

determining a critical contact line density "Λ_L" value according to the formula:

$$\Lambda_L = \frac{-P}{\gamma\cos\left(\theta_{a,0} + \omega - 90^\circ\right)}$$

where P is the predetermined pressure value, γ is the surface tension of the liquid, $\theta_{a,0}$ is the experimentally measured true advancing contact angle of the liquid on the asperity material in degrees, and ω is the asperity rise angle;

providing a membrane body portion with a multiplicity of micropores defined therein; and

forming an ultraphobic surface on the membrane body portion, the ultraphobic surface comprising a substrate with a multiplicity of projecting asperities, the asperities disposed so that the surface has an actual contact line density equal to or greater than the critical contact line density.

15. The process of claim 14, wherein the asperities are formed using nanomachining, microstamping, microcontact printing, self-assembling metal colloid monolayers, atomic force microscopy nanomachining, sol-gel molding, self-assembled monolayer directed patterning, chemical etching, sol-gel stamping, printing with colloidal inks, or by disposing a layer of parallel carbon nanotubes on the substrate.

16. The process of claim 14, further comprising the step of selecting a geometrical shape for the asperities.

17. The process of claim 14, further comprising the step of selecting an array pattern for the asperities.

18. The process of claim 14, further comprising the steps of selecting at least one dimension for the asperities and determining at least one other dimension for the asperities using an equation for contact line density.

19. The process of claim 18, further comprising the step of determining a minimum contact line density.

20. The process of claim 14, further comprising the step of determining a critical asperity height value "Z_c" in meters according to the formula:

$$Z_c = \frac{d\left(1 - \cos\left(\theta_{a,0} + \omega - 180^\circ\right)\right)}{2 \sin\left(\theta_{a,0} + \omega - 180^\circ\right)}$$

where d is the distance in meters between adjacent asperities, $\theta_{a,0}$ is the true advancing contact angle of the liquid on the surface in degrees, and ω is the asperity rise angle in degrees.